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INVESTIGATION OF MATERIALS FOR SHIP-TO-SHORE LOW PRESSURE STEAM--ETC(U)
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Technical Note

CEL

TN no. N-1495

title: INVESTIGATION OF MATERIALS FOR SHIP-TO-SHORE LOW PRESSURE STEAM HOSES

author: Thorndyke Roe, Jr.

date: July 1977

sponsor: NAVAL FACILITIES ENGINEERING COMMAND

program nos: YF53.534.091.01.122

CIVIL ENGINEERING LABORATORY
NAVAL CONSTRUCTION BATTALION CENTER
Port Hueneme, California 93043

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TN-1495	2. GOVT ACCESSION NO. DN687037	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INVESTIGATION OF MATERIALS FOR SHIP-TO-SHORE LOW PRESSURE STEAM HOSES		5. TYPE OF REPORT & PERIOD COVERED Not final; Jul 1975 - Jun 1976 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Thorndyke Roe, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS CIVIL ENGINEERING LABORATORY Naval Construction Battalion Center Port Hueneme, California 93043		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62760N; YF53.534.091.01.122
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Facilities Engineering Command Alexandria, Virginia 22332		12. REPORT DATE July 1977 13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hoses, steam, materials, ship-to-shore.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Civil Engineering Laboratory
INVESTIGATION OF MATERIALS FOR SHIP-TO-SHORE LOW PRESSURE STEAM HOSES, by Thorndyke Roe, Jr.
TN-1495 18 pp illus July 1977 Unclassified

1. Steam hose 2. Ship-to-shore hose 1. YF53.534.091.01.122

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CONTENTS

INTRODUCTION

The President, Board of Inspection and Survey (INSURV), Department of the Navy, in a memorandum to the Chief of Naval Material, indicated a problem with the delivery method of shore steam to ships at the Naval Stations at Norfolk, Virginia and Mayport, Florida. The rubber tube (inside wall) of steam hoses deteriorated in service and small particles of rubber passed through strainers and entered the ship's low pressure steam system. Thus, galley and laundry equipment, heating and hot water systems, evaporators, and the main condensate system became contaminated. INSURV also indicated that this problem has existed for many years.

The Naval Facilities Engineering Command (NAVFAC) requested that the Civil Engineering Laboratory (CEL) study this problem with suggested emphasis on:

1. Causes of steam hose failure
2. Determination of the most suitable materials for steam hoses
3. Adequacy of the present procedures used for testing steam hoses
4. Procedures for repairing steam hoses

FIELD INFORMATION ON STEAM HOSE PERFORMANCE

Various Naval activities were contacted by NAVFAC, or the Civil Engineering Laboratory, either directly or through the RDT&E Liaison Officers at the Engineering Field Divisions, for information on performance of steam hoses. Available service life information obtained is summarized in Table 1; field maintenance and operating problems are summarized in Table 2.

Causes for Failure

Steam hoses deteriorate for many reasons such as heat aging, chemical attack, abuse, and mechanical damage.

Heat Aging. Heat aging results in either softening or hardening of rubber products used for the tube, cover, and adhesion layers of steam hoses. In the former case, the tube loses strength; in the latter, it cracks. When used for saturated steam service, the tube material

absorbs hot water. When the pressure is released, this water flashes off as steam and causes tears to develop in the tube surface. After several pressurization-depressurization cycles, bits of the tube surface material are torn away, thus producing the ''popcorning'' effect. Steam can pass through the tube material to form blisters filled with steam or hot air under the cover. Some manufacturers perforate the cover with tiny holes to reduce the possibility of this occurrence.

Chemical Attack. The cover can be attacked by chemicals, especially fuels and oils, and by ozone and oxygen. When the temperature of the cover is increased during operation, the rate of degradation increases.

Abuse. Use plus abuse can greatly shorten the service life of a steam hose. Kinking, twisting, or hanging hose on a peg for storage can cause mechanical damage to it, and the amount of damage caused will increase as the hose components are affected by heat aging. Connecting a hose to a horizontal steam line at the ship causes a sharp (90 degree) bend in the hose and subsequent early failure.

Mechanical Damage. Allowing the hose to lie unprotected on wharf decks where vehicles, especially forklift trucks, can run over it also causes mechanical damage. Abrasion by rubbing on hawsers or on the pier also causes early failure.

Other Comments

Sherman [1], Naval Ship Research and Development Center, after reviewing MIL-H-28596, stated that hose which qualified under this specification should give satisfactory service. He gave two possible reasons for early failure:

1. The manufacturer used an inferior rubber compound for the tube of the hose furnished in place of the good compound used for the tube of the hose tested.

2. The manufacturer got a waiver from the Navy on the hose furnished.

The Civil Engineering Laboratory concurs with these opinions. Also, CEL learned that because hose which meets MIL-H-28596 is manufactured on special order (with subsequent long delivery times), field activities have purchased nonspecification hoses which have sometimes given unsatisfactory service.

MATERIALS FOR STEAM HOSES

Information From Hose Manufacturers

In reviewing Military Specification MIL-H-28596 it was found that the specification details the wire reinforcement, coupling components, and construction, but for the rest of the hose specifies only that "rubber compounds, either natural or synthetic or combinations thereof, used in the construction of the hose shall be heat-resistant. In addition, the cover shall be resistant both to abrasion and ozone cracking."

In order to obtain information on the availability of, and materials used in the manufacture of steam hoses for use with saturated steam at 200 to 250 psi (14.1-17.6 kg/cm^2), the Visual Search Microfilm file was reviewed for possible manufacturers. Inquiries were sent to 16 companies. Two basic questions were asked:

1. Does your company manufacture a hose which qualifies under MIL-H-28596?

2. Does your company manufacture a hose which meets the performance requirements of MIL-H-28596 but does not meet the design requirements?

Eight replies were received; only two were affirmative. Acme-Hamilton Manufacturing Corporation, P.O. Box 362-T, Trenton, New Jersey 05603, and Gates Rubber Co., 999 S. Broadway, Denver, Colorado 80217, manufacture hoses which qualify under the military specification. The rubber materials used by these companies to fabricate these hoses are specially compounded and are proprietary.

Information Obtained From the Literature and Personal Communications

Three other information sources indicate that EPDM (ethylene propylene diene monomer) rubber, also called EPT (ethylene propylene terpolymer) rubber is the most desirable for steam hoses used by industry. Burton [2] states that through the use of EPDM rubber, the highest rated steam hose has a life expectancy of over 1,500 hours with saturated steam at 406°F (208°C) or with superheated steam at 450°F (232°C). Machine Design [3] states that EPDM elastomers perform best in contact with saturated steam up to 250 psi (17.6 kg/cm^2). In its brochure on Nordel®, which is an EPDM rubber, DuPont [4] states that this material, in round-the-clock use has a life of 1 year (more than 8,000 hours) carrying 150 psi (10.6 kg/cm^2) saturated steam at 360°F (182°C), and three months (more than 2,000 hours) carrying 250 psi (17.6 kg/cm^2) saturated steam at 407°F (208°C). On the other hand, Loke [5] states that, although it will not meet the physical requirements of the 1,000-hour steam test of MIL-H-28596, steam hose with a chlorobutyl tube would be free of the popcorn effect. None of the above sources mentioned intermittent service which is potentially more damaging than continuous

service. CEL is now evaluating five different hoses in actual service. A preliminary evaluation will be available after in-service use.

EPDM rubber is also suitable for the cover of a steam hose except where contact with oils or fuels is possible; neoprene is suitable in the latter cases.

It must be stated that, although a specific type of rubber is mentioned as being used in the fabrication of a hose, this rubber is compounded (i.e., blended) with vulcanizing agents, accelerators, activators, antioxidants, fillers, pigments, and softeners which affect the mechanical and physical properties of the end product. Research by industry continues for more steam-resistant elastomeric materials. Also, available materials which are not generally used for steam hoses have been investigated for this use, but none was superior to the best rubber hoses available. For example, two lengths of polytetrafluoroethylene (Teflon®) hose were evaluated by a hose producer at San Diego; the hose failed because it could not stand the necessary flexing.*

Thus, it follows that any specification for steam hose must be based on performance rather than on materials. Sherman [1] suggests that tensile strength and ultimate elongation before and after the steam test should be specified. Also, the adhesive strength of various plies - tube to braid, between braids, and braid to cover - should be specified. CEL concurs with these suggestions.

Repair

Table 2 gives modes of hose failure and repair techniques used in the field. Rubber hoses are repaired by cutting out the deteriorated section and installing couplings.

Stainless steel-lined and fiberglass braid-lined steam hoses have been used by many Navy activities with some degree of success. The manufacturer of the stainless steel-lined hose states that this hose can not be field-repaired, but it can be factory-repaired [6]. Economic considerations will have to be determined by the user.

SUGGESTED OPERATION PROCEDURES TO OBTAIN MAXIMUM SERVICE USE FROM STEAM HOSES

1. Maintain operating pressure and temperature to the minimum required for adequate service.

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*The possibility of silicone rubber hose for steam was considered, but according to a manufacturer of silicone rubber hoses for automotive applications, it would not be suitable for this use.

2. Reduce pressure in the hose slowly when terminating service to prevent flashing off of hot water condensed in the pores of the tube, thus greatly lessening the possibility of popcorning. See Appendix A for one suggested system to accomplish this. Long Beach and San Diego Naval Stations report that at termination of service, valves are closed at the ship end of the hose and at the pier. The hose is disconnected from the ship, after which the ship-end valve of the hose is opened slightly to bleed off the steam pressure. Every effort possible should be made to keep the disconnected hose from falling into the water or from hitting the pier.

3. Avoid twisting the hose. Route it so it flexes in a single plane.

4. Use fittings where sharp bends are required. The minimum bending radius (inside) should be not less than ten times the outside diameter of the hose. Where the intake fitting is flush with the side of the ship, a fitting should be available so that the steam hose can be connected in a downward direction. Figure 1 shows a 90-degree hose bend at a horizontal intake where early failure occurred (see Appendix B).

5. Where the hose must be laid across a wharf deck, place planks on both sides of it in areas where heavy vehicles such as forklift trucks must cross over it.

6. Before storing a hose, drain it and wipe off the cover. Hang it on a large radius (see item 4 above) wall bracket or lay it on a flat surface. Store it in a cool, dry place.

7. Use strainers and maintain them properly.

CONCLUSIONS

It is concluded that:

1. Rubber steam hose that meets the requirements of MIL-H-28596, with careful use can have a service life of up to 1 year.

2. Use of good ''housekeeping'' procedures to avoid mechanical damage to the hose and to insure proper storage of hose will increase its service life.

3. Avoidance of sharp bends where the hose is connected to the ship and protection from abrasion will increase hose life.

4. Slow release of steam pressure at termination of service will increase the life of a steam hose.

RECOMMENDATIONS

1. It is recommended that instructions on procedures and responsibilities for the use and care of steam hoses and strainers be issued by the Naval Sea Systems Command for shipboard personnel and by NAVFAC for public works personnel.

2. When early failures of specification hoses occur, the user (field activity) should notify the supplying agency.

FUTURE PLANS

Initially, five different types of steam hose were obtained in 25-foot lengths. These are:

1. Hoses which meet MIL-H-28596
2. Glass braid-lined rubber hose (this was found to be identical to the specification hose obtained for this study)
3. Stainless steel-lined 1-1/2-inch rubber hose (EPDM-butyl rubber tube)
4. Stainless steel-lined 2-inch rubber hose (EPDM-butyl rubber tube), 2 each
5. Rubber hose with chlorobutyl rubber tube

Later, two lengths of a new steam hose with, according to the manufactorer, an improved tube material, were furnished to CEL. One of these hoses also was fitted with a stainless steel liner. The manufacturer states that both of these hoses should have equal service lives.

With the cooperation of the Public Works Department, Naval Construction Battalion Center, Port Hueneme, California, these hoses are being evaluated under actual service conditions in supplying steam to the USS NORTON SOUND. Appendix B contains initial results of the field evaluation of the steam hoses being tested. Results are expected by the end of 1977.

ACKNOWLEDGMENT

The author wishes to thank Mr. Robert S. Chapler, Mechanical Systems Division, CEL, for his design of a low pressure release system for steam hoses.

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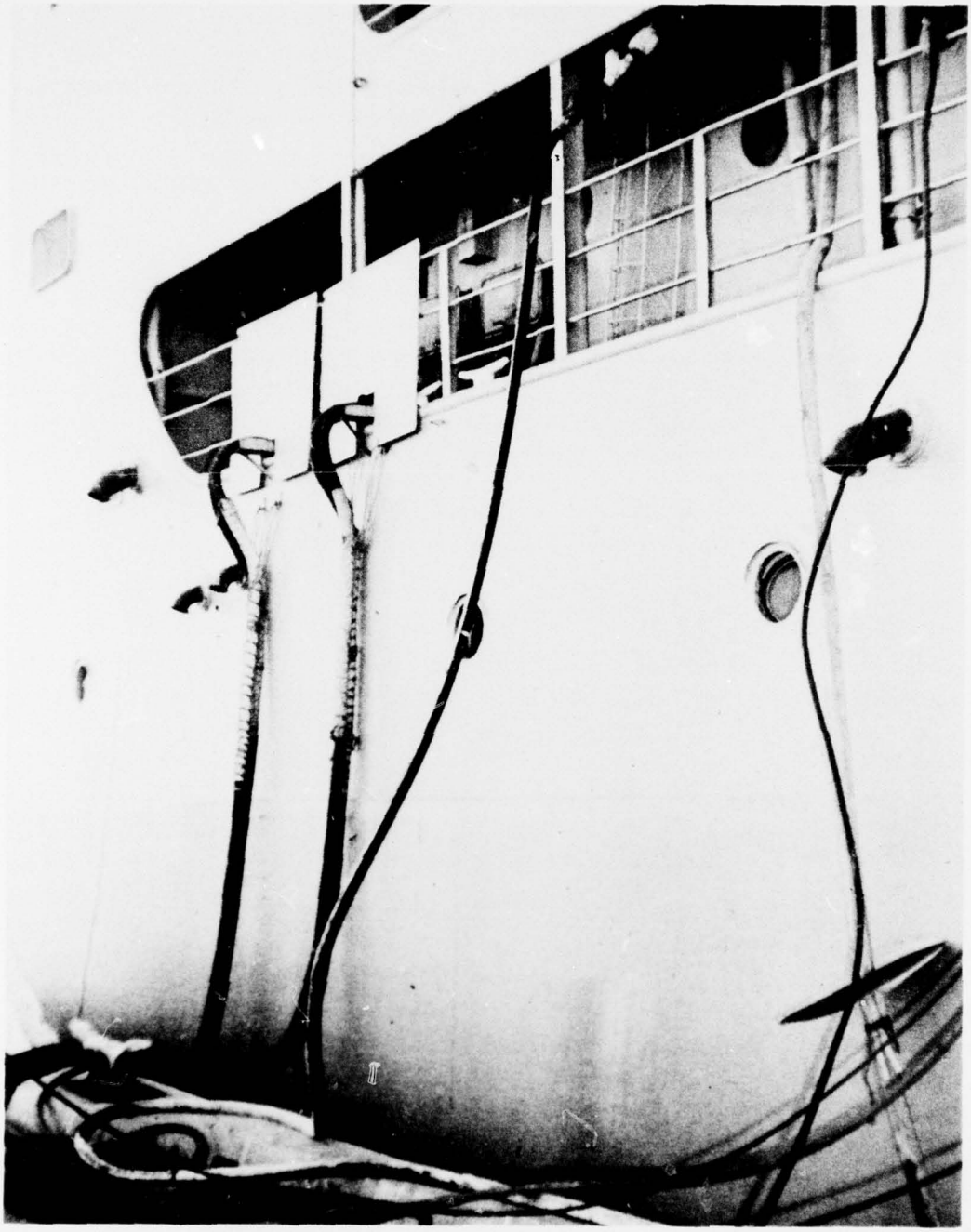

Figure 1. Sharp 90-degree bends in steam hoses at ship's intake.

Table 1. Field Service Life of Steam Hoses

(Based on 25-ft-length, 2-in.-diam, uncoupled hose.)

Tube Material	Cover Material	Service Life	1977 Cost ($)	Weight (lb)	Location
Chlorobutyl	–	71 days OK[a] 48 days OK[a] 1 day leaked[a]	158[b]	40.2[b]	Norfolk, Va.
Chlorobutyl	Neoprene	3 – 6 months	–	–	North Island, Calif.
EPDM[c]	Butyl	8 – 10 months	317	45.0	Pensacola, Fla.
EPDM	EPDM	3 months	–	–	Mayport, Fla.
Stainless Steel, EPDM	EPDM	2 weeks – 6 months	294	65.0	Portsmouth, N.H.
Stainless Steel, EPDM	EPDM	4 months	294	65.0	Concord, Calif.
Stainless Steel, EPDM	EPDM	4 – 6 months	294	65.0	Norfolk, Va.
Stainless Steel, EPDM	EPDM	6 months	294	65.0	Long Beach, Calif.
Stainless Steel, EPDM	EPDM	>6 months	294	65.0	Subic Bay, P.I.
Stainless Steel, EPDM	EPDM	>1 year	294	65.0	Mayport, Fla.
Rubber[d] (Proprietary)	Rubber[d] (Proprietary)	6 months	183	43.8	Port Hueneme, Calif.
Rubber[d]	Rubber[d]	3 months	187[f]	43.8	Pearl Harbor, Hawaii
Rubber[d]	Rubber[d]	<6 months	187[f]	43.8	Subic Bay, P.I.
Rubber[d]	Rubber[d]	6 months	187[f]	43.8	Norfolk, Va.
Rubber[d]	Rubber[d]	12 – 14 months	187[f]	43.8	Yokosuka, Japan
Metal[e]	Metal[e]	6 months	203[f]	67.5	Philadelphia, Pa.
Metal[e]	Metal[e]	1 – 2 years	203[f]	67.5	Charleston, S.C.

[a] One hose, three deployments.

[b] Assumed to be Gates 205MB.

[c] Ethylene propylene diene monomer.

[d] Meets MIL-H-28596A, nominally in 50 ft lengths.

[e] Meets MIL-H-18160B, in lengths not less than 25 ft unless otherwise stated (similar to shipboard stock item).

[f] Twenty-five-foot length, with couplings.

Table 2. Field Maintenance and Operating Problems with Steam Hoses

Facility	Field Repair Techniques Used	How Are Strainers Maintained?	Are There Rubber Contamination Problems From Hoses Purchased Under MIL-H-28596?	What Were The Causes of Failure For All Hoses?
Public Works Center, Subic Bay	Replacement of damaged fittings with usable fittings from old or discarded steam hoses.	Not maintained. New strainers installed upon request from the ships force.	No hose purchased under MIL-H-28596. Have used MIL-H-19030 (superseded by MIL-H-28596).	Rough usage or weathering. No failures in stainless steel-lined hose.
Ship Repair Facility, Yokosuka	No field repair. Hoses brought into shop for repair.	Cleaned and inspected after each use. If inside mesh is found damaged, it is replaced.	No hose purchased under MIL-H-28596. Have used MIL-H-19030 (superseded by MIL-H-28596).	Internal fiberglass lining fails; comes loose from outer jacket.
Puget Sound Naval Shipyard	None. Defective or deteriorated hose is replaced.	Serviced when a system parameter demonstrates need.	Strainers used are believed to be effective in preventing carry over of rubber particles into ships' steam systems.	Hoses vary widely in performance. Fiberglass braid reinforced hose seems to deteriorate very quickly in service.
Supervisor of Shipbuilding, Conversion and Repair, Bath, Maine	Hose purchased in 100-ft lengths. Damaged portions cut out, couplings installed. If large percentage of length has deteriorated, hose is replaced.	Cleaned with compressed air.	No hose purchased under MIL-H-28596.	No single agent or action has been determined as the main cause of failure. Preservative in steam, intermittent use in a hostile environment, condensate freezing in hoses, heavy vehicles running over are causes.
Public Works Center, Naval Air Station, Pensacola	When practical, hoses are cut and fittings reinstalled.	Strainers are located on board ships and are maintained by shipboard personnel.	No.	Sunlight, moisture, and salt air exposure, and dragging the hoses over concrete docks are the primary causes of failure.
Naval Weapons Station, Earle, N.J.	Hoses about 2 years old. No occasion to make repairs.	Two strainers on Muse steam trailer. Serviced during boiler preservative maintenance.	No hose purchased under MIL-H-28596. Purchased hose from Goodyear Rubber Products.	Prior to purchase in 1974, had problems with outer jacket blistering. No problems so far with Goodyear hose.
Norfolk Naval Shipyard	None, other than installing gaskets as needed.	Inspected periodically and replaced as necessary.	No.	No specific cause has been determined. Most common failure is the development of pinhole leaks.
Naval Weapons Station, Charleston	Replacement of connectors.	No strainers used.	None to date.	No problems experienced with steel reinforced hoses to date.

continued

Table 2. Continued

Facility	Field Repair Techniques Used	How Are Strainers Maintained?	Are There Rubber Contamination Problems From Hoses Purchased Under MIL-H-28596?	What Were The Causes of Failure For All Hoses?
Pearl Harbor Naval Shipyard	None. Hoses replaced.	No strainers used.	Hose purchased under MIL-H-19030 (superseded by MIL-H-28596). No contamination problems.	No failures experienced.
Mare Island Naval Shipyard	None. Hoses are replaced.	Installed when required with no specific maintenance program for short durations. Inspected and cleaned or replaced prior to reinstallation.	No.	Weathering is primary cause. There is no record of failure of steel hoses (MIL-H-18160).
Naval Weapons Station, Concord	None. Hoses are purchased in short lengths so that when damaged they can be discarded.	Cleaned with a wire brush after each ship leaves.	No hoses purchased under MIL-H-28596. Purchased hoses are steel lined.	Physical abuse such as being run over by forklift trucks, or bending sharply.
Long Beach Naval Shipyard	None.	Cleaned after each use.	Yes. Now steel-lined hoses are used.	Normal wear of rubber cover.
Charleston Naval Shipyard	Shortening hoses which have been cut or are leaking.	Inspected and cleaned prior to each use, if necessary.	None since strainers have been used.	Age and weathering. (Inspection and hydro testing prior to each use detected weak or worn hoses).
Headquarters, Naval District, Washington, D.C.	Connectors are replaced.	Inspected and maintained on a monthly basis.	Yes. Because of this, hose is no longer purchased under MIL-H-28596.	Coiling, connecting, disconnecting, and structural damage from vehicular traffic, forklift trucks, and crane damage.
Naval Station, Mayport, Fla.	Ruptured sections cut out and couplings installed on severed ends.	Maintained by ships' personnel.	No hoses purchased under MIL-H-28596.	Rubber hoses fail because of deterioration and flaking of the rubber lining and because of ruptures. Failures of steel-lined hoses are mostly ruptures.
NCBC, Port Hueneme	Rarely made. If break does occur, hose would be cut and spliced with new fittings.	If strainers aboard ship, maintained by ships' personnel. If not aboard ship, maintained by station personnel on a weekly schedule.	One shipment of B.F. Goodrich hose created some minor flaking problems.	One steel-lined hose has had no failure to date. Rubber-lined hoses have general blistering.

continued

Table 2. Continued

Facility	Field Repair Techniques Used	How Are Strainers Measured?	Are There Rubber Contamination Problems From Hoses Purchased Under MIL-H-28596?	What Were The Causes of Failure For All Hoses?
Portsmouth Naval Shipyard	None.	No strainers used.	No hose purchased under MIL-H-28596.	Use steel-lined hose. Hose can get pinched.

Appendix A

SLOW PRESSURE RELEASE SYSTEM FOR STEAM HOSES

By Robert S. Chapler
Mechanical Engineer
Mechanical Systems Division
Civil Engineering Laboratory

A procedure to prevent rapid pressure release in steam hose consists of: (1) closing both the ship's stop valve and the flexible hose terminating stop valve, (2) disconnecting union at ship's line between valves, (3) closing dockside stop valve, and (4) allowing hose to cool slowly, with the vacuum check valve preventing pressure inside the hose from dropping below atmospheric. The hose and valve system is shown schematically in Figure A-1.

The rate of decrease in internal pressure will depend upon the heat loss from the hose section, but it should take less than 5 minutes to reach one atmosphere. If pressure decrease appears to be too rapid one could crack the dockside steam valve and bleed the steam into the hose to slow the rate of pressure decrease.

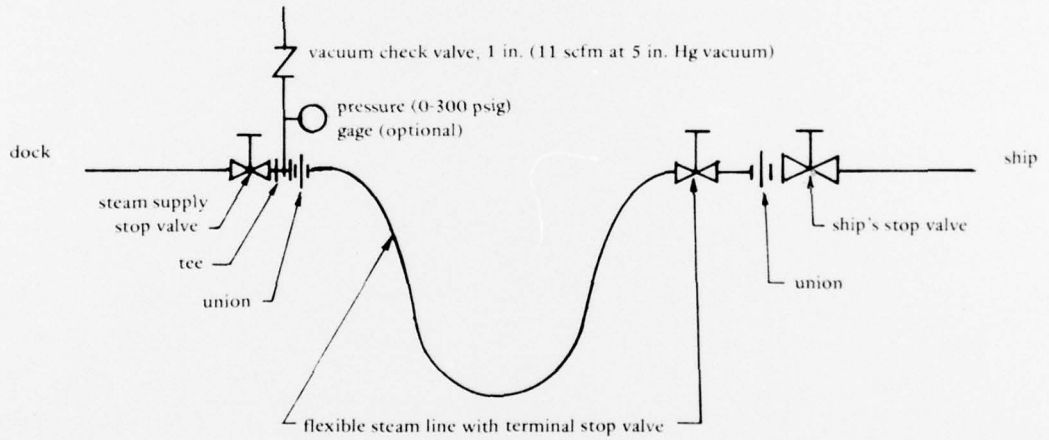

Figure A-1. Steam hose and valve system.

Appendix B

INITIAL RESULTS OF FIELD EVALUATION OF SPECIFICATION AND NONSPECIFICATION STEAM HOSES

In August 1976, six steam hoses were placed in service to supply the USS NORTON SOUND at Port Hueneme, California. These hoses are:

1. Hose which meets MIL-H-28596
2. Glass braid-lined rubber hose (found to be identical to the specification hose obtained for this study)
3. Stainless steel-lined 1-1/2-inch rubber hose (EPDM-butyl rubber tube)
4. Stainless steel-lined 2-inch rubber hose (EPDM-butyl rubber tube), 2 each
5. Rubber hose with chlorobutyl tube

These hoses were removed from service temporarily in January 1977 when the USS Norton Sound was undergoing refitting at Long Beach. One of the glass braid-lined rubber hoses had sustained abrasion damage on one end after 112 days of intermittent service. When the damaged section was cut off so that the fitting could be reinstalled, it was found that the glass braid liner had deteriorated; thus, the hose had to be discarded (Figure B-1). One 2-inch stainless steel-lined rubber hose had sustained cover damage after 110 days of intermittent service. This occurred where the hose made a sharp 90-degree bend adjacent to the ship's inlet line (Figure B-2). Because this hose cannot be field-repaired, it was removed from service.

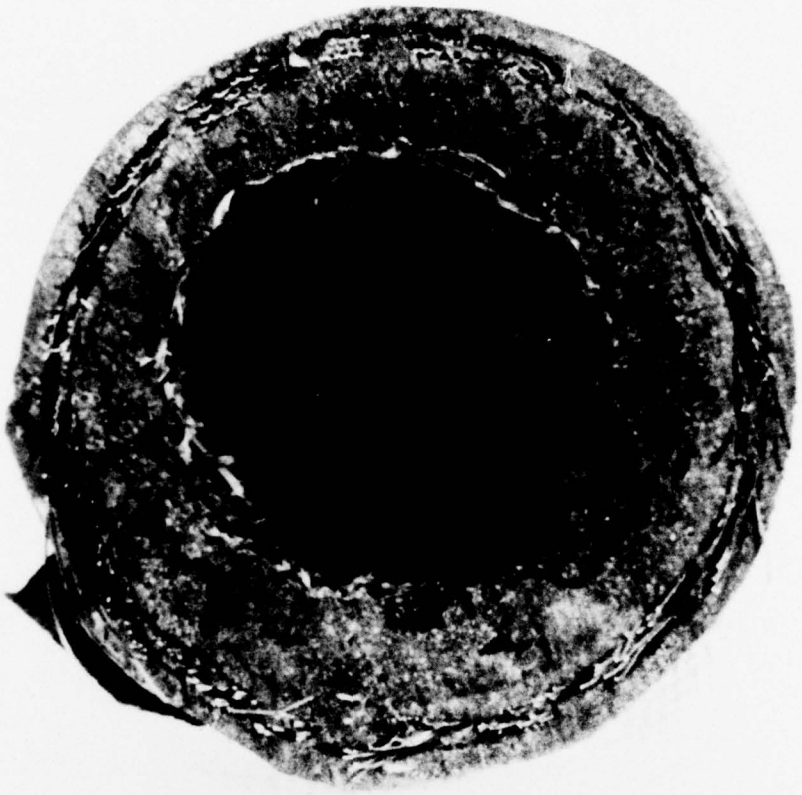

Figure B-1. Deteriorated glass braid-lined steam hose.

Figure B-2. Cover damage of 2-inch stainless steel-lined rubber hose caused by sharp 90-degree bend at ships's intake.

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